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ORIGINAL ARTICLES.

Earth Movements and Extinction.

By H. H. SWINNERTON, D.Sc., F.G.S., F.Z.S.

A CENTURY or more ago, when catastrophic theories held the field, it was believed that the history of the world was made up of a succession of short periods of intense earth movement alternating with prolonged periods of tectonic calm. The movements were so vigorous and violent in their action that all forms of life were wiped out completely, and the earth was subsequently repeopled by acts of special creation.

Though such views, in all their baldness, are no longer held, their modified counterpart crops up in present-day geological teaching under the guise of "cycles of earth-movement" and "cycles of evolution" and of a presumed causal relation between the two. Thus in a recent deservedly popular text-book[1] we are told that "The rise of fishes is closely connected with Siluro-Devonian earth movements". The rise and fall of reptiles are similarly correlated with the Carbo-Permian and Cretaceo-Tertiary movements respectively. The coming and going of Graptolites, Trilobites, and Ammonites are likewise associated with periods of mountain building. A kindred point of view is found in another book upon "Ice Ages", in which we are told that "these short spells of trial and stress meant far more for the development of the world's inhabitants than all the long periods of ease and sloth when the earth was a hot-house".[2]

These generalizations explain so much, and reflect so exactly the wish that is father to the thought, that, following the advice of T. H. Huxley, they should be received with suspicion. The fact that such views are being passed on as established to other than geological audiences[3] renders it necessary to examine the grounds upon which they are based.

The general history of the Trilobites is relatively simple, and well illustrates the main principles of racial decline and extinction. These organisms came into being in Pre-Cambrian times, and progressed, with increase in numbers of genera and species and varied adaptation to different habitats, throughout the Cambrian. They attained the acme of their development during the Ordovician, but from the latter end of that period onwards they experienced a prolonged but steady decline. Their passage into Silurian times was accompanied by the disappearance of about one-third of the stock. Only one-half of the remainder persisted far into Devonian times; whilst but two, possibly three, genera survived long enough to live in Carboniferous waters and be subjected to the vicissitudes entailed by Carbo-Permian earth movements. Had the Trilobites obtained their acme during the Carboniferous period, and then had all disappeared simultaneously, there might have been some justification for claiming a causal relation between those movements and their extinction. In actual fact, as shown by the figures given above, the influences which brought about their ultimate and complete extinction came into action before the close of the Ordovician, and continued acting from that time onwards. Obviously there can have been no causal relation between the Carbo-Permian orogenic movements and the gradual, age-long, and successive disappearance of the various trilobite genera and species, unless one believes in anticipatory fright as a counterpart to racial memory. Even the last trilobite seems to have expired a million years or so before the Carbo-Permian movements actually began.

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[1] L. Dudley Stamp, *An Introduction to Stratigraphy*, 1922, p. 22.

[2] A. P. Coleman, *Ice Ages, Recent and Ancient*, 1926, p. xxii.

[3] H. J. F., "Some New Work on the History of the Earth's Surface": *Geographical Teacher*, 1925, p. 192.

The case of the Ammonites is more complicated, but is nevertheless more instructive. The Ammonoidea, of which the Ammonites are but a section, came into being at the close of the Silurian and the opening of the Devonian. They progressed steadily, producing new genera, families, and orders throughout Permian times; and reached their acme during the Triassic period. All this happened quite irrespective of the fact that Carbo-Permian movements had begun and ended during the interval. Towards the close of the Triassic and during the Rhaetic periods, species, genera, families and even orders followed one another so rapidly to extinction that the stock all but disappeared. This is an outstanding case of rapid decline, but it took place, unfortunately for the views now being discussed, during a period of tectonic calm.

A small remnant of the Ammonoidea, however, survived that fateful time, and gave rise to that ammonite fauna which was so abundant during a period "of ease and sloth" in the Jurassic waters even of the British Isles. Their story, as every student of the Mesozoic rocks knows to his sorrow, is one long wearisome reiteration of the coming into being of new types which lived but a short while and then became extinct. This fact, though it renders the Ammonites extremely valuable as indicators of time, runs counter to the idea of there being any such clear-cut relation between ice ages, earth movements, and extinction as that referred to above.

During the later Jurassic and early Cretaceous periods the wonderful fecundity of the stock diminished. A number of abortive forms were produced in some mysterious effort to find a way of escape from complete extinction. This was of no avail. A few short-lived genera, the last products of a race that had survived various periods of "trial and stress" as well as of "ease and sloth", were all that were left. They became extinct whilst as yet the Cretaceo-Tertiary earth movements were merely in their birth-throes.

The same story may be repeated with variations for all the other great groups of marine organisms. Occasionally such movements isolated portions of the sea and converted them into land with the consequent extinction of those organisms that happened to be trapped. The area thus isolated has, however, always been only a fragment of the whole. Abundant accommodation has always been left for the multitudinous marine population that escaped. On the whole, such movements merely shifted, they did not destroy, shore lines and submarine habitats. This shifting took place so slowly that most of the members of a fauna were able to migrate with the habitat or become adapted to the new one which overtook them.

It should not be overlooked that if mountain-building movements were really effective in bringing about extinction of stocks, then all stocks should experience periods of rapid extinction contemporaneously with one another. This, however, has not been the case. On the contrary, the period during which decline takes place, and the rate at which it proceeds, are peculiarities of each group. Compare, for example, the rapid sequence of events in the racial history of the graptolites with the more stately progress and decline of the trilobites.

Turning now to terrestrial faunas it is natural to expect that they will reflect more distinctly the influences of the "turmoil of a great orogenic movement". As with Ammonites and Trilobites, so with Reptiles and Mammals, the production of new kinds and the extinction of old ones have gone on hand in hand with one another throughout the long periods of their racial histories. When production is more rapid than extinction the race is said to be progressing to its acme, but when the reverse is the case, the race is said to be declining. Earth movement, especially of the orogenic type, may play a part in the production and extinction of a few kinds, but the portion of the earth's crust so affected at any one period of time is small compared with the area of the stable shields. On these, in all ages including the present, there has always been ample room for the majority of the representatives of all the races which make up the fauna, and from them the less stable regions have been repopulated.[1] On the other hand the mountains are merely a place of refuge for a few.

As for the Ice Ages, many Proboscidea had come and gone before the onset of the Quaternary glaciation, and some are with us still. Meanwhile only a very few species came within the sphere of influence of Arctic conditions. Of these even the Mammoth survived two cycles of glaciation, and in the end appears to have been troubled more by the quagmires of Asia and the hunting parties of post-glacial Magdalenian man than by any vicissitudes of climate.

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[1] H. F. Osborn, *Age of Mammals*, 1910, p. 67, and subsequent work in Mongolia.

It may be that we are still living during an Ice Age or that mountain building is still proceeding, but the throb of life is now, as in all ages, far removed from the " silent North " and the " mountain solitudes "

Deductions from Established Facts in Geology, by Wm. Smith: Notes on a Recently Discovered Broadsheet.

By F. J. North, D.Sc., F.G.S., National Museum of Wales.

WILLIAM SMITH'S known writings deal almost exclusively with the practical application of the principles he discovered and enunciated.

He was, as his nephew and biographer, John Phillips, records, " remarkably disinclined to indulge in himself, or even to tolerate in others, mere speculation in geology," and, as a young man, he emphasized the necessity for caution on the part of those who " set about to invent a system which nature cannot conform to without having recourse to uncommon convulsions by which every hill and dale must have been formed ".

It is, however, impossible to suppose that a man of such remarkable mental activity could have had no opinions concerning the earlier stages of the earth's development—the subject of many books by his predecessors and of much discussion among his contemporaries ; but of his views we have hitherto known practically nothing, except that he did not consider " The Deluge " to have been any more than an episode in the earth's history, and that he regarded *only* the widespread superficial gravelly deposits containing boulders and bones as attributable to " diluvial " action. He did not subscribe to extravagant views like those of John Woodward, for he wrote :—

> " I verily believe that those waters did not penetrate to such a depth, nor disturb the strata so much as had been imagined : yet the effects of a deluge are very visible upon the surface of the earth, . . . especially in low lands by the sides of large rivers, where great quantities of gravel, sand, and mud, are generally collected, in which the remains of trees and animals are frequently found preserved entire. And these are the things which may be reckoned among the most perfect proofs of a deluge, but at the same time they must not be mistaken for or confounded with the fossils of a very different description and of a different origin, such as the exuviae of marine animals and vegetable impressions, which are always found regularly imbedded in the solid strata." [1]

[1] MS. of about 1797, quoted by J. Phillips in *Memoirs of Wm. Smith*, London, 1844, p. 25.

Many years later, he tabulated his views concerning the place and importance of the Deluge in the scheme of geology in a single sheet entitled, *Synopsis of Geological Phenomena*, published at Oxford in connexion with the second meeting of the British Association in 1832. The extracts given in Table 1 will serve to illustrate the nature of this remarkable document of which very few copies appear to have survived. Of these, one is in the Library of the Geological Society, and, in smaller type, a printed copy appears in Sheppard's paper " William Smith : his maps and memoirs ".[1]

It has been the writer's good fortune recently to discover a copy of another broadsheet, published by Smith in 1835—three years after the appearance of the " Synopsis ", which has hitherto been regarded as his last separate publication. The sheet is of special interest, for it contains a summary of Smith's opinions concerning the whole series of events, which, culminating in " The Deluge " and a " Change of climate ", resulted in the present condition of things.

It is headed " Deductions from Established Facts in Geology ", and at the bottom is printed :—

" WILLIAM SMITH,
Scarbro', July 21 1835."
" C. R. Todd, Printer, &c., 73, Newborough Street, Scarborough."

The sheet is too large (12 in. by 15 in.) to be reproduced as a plate in this magazine, but its general character may be judged from the extracts given in Table 2.[2]

There appears to be no record of the circumstances under which the sheet was published, but it was printed in the year following Smith's retirement to Scarborough, after six years spent on the Hackness estate of his friend, Sir John Johnstone. It was his intention on retiring, to rearrange his manuscripts, and to complete, if possible, the various investigations in which he had for many years been engaged, but the faculty for observation which was so remarkable during his field-working days was still as active as ever, and he continued to accumulate material, with the result that " papers which required re-arrangement and consideration were augmented, and connected with new trains of research ",[3] and of the ever-increasing mass of manuscript little was published.

From its opening paragraph, it would appear that Smith felt constrained to publish the " Deductions ", partly to emphasize further the importance of fossils as a means of interpreting earth-history, and partly in answer to inquiries that had been addressed to him upon the subject: it will be shown later that there are good reasons for believing that it was prompted by the perusal of Lyell's "Principles" which, first published in 1830, had already reached its fourth edition.

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[1] *Proc. Geol. Soc. Yorkshire*, N.S., vol. xix, 1922, pp. 75–253.

[2] The original broadsheet will be deposited in the Library of the Geological Society where there are already other documents relating to the " Father of English Geology ", but I am indebted to Dr. F. A. Bather for the suggestion that some who are interested in the history of Geology in this country might wish to have copies. It has been ascertained that photostat copies could be made at a cost of about 2*s*. each, and if any who desire to have them will communicate with the writer the necessary arrangements can be made.

[3] J. Phillips, ibid., p. 119.

The sheet commences:—

> "As doubts may remain in the minds of many of the PRINCIPLES of GEOLOGY, I shall endeavour to exhibit the principles, long familiar to my mind, in a clear view, opened by the organized Fossils, which are the medals of Creation, the antiquities of nature, and records of time.
>
> "It is certain that by the use of these in Geology we are carried back into a region of supernatural events, not merely to believe, but to see much of what there occurred; yet beyond a certain extent we cannot go; therefore we must be content to pass over the primitial interior of the Earth, and see that in the Stratification there have been CONSECUTIVE CREATIONS and DESTRUCTIONS under water, which may be thus arranged."

Then follows the title, "Deductions from established facts in Geology."

The first period he recognized was one void of life, an "Order of things in which crystalization prevailed", during which the primitive rocks were formed. When stratification commenced, that was also "*The commencement of living beings*—physical operations, life, growth, and propagation of species", and the animals were "*Physically* subject to the extinction of life, by decay, or by being the prey of other animals".

This was followed by a "New order of things essentially different from any 'causes now in operation'—distinguished by general destruction". The evidence for the new order of things was that "stratification became occupied by new races of animals". This, he supposed, indicated that the animals first created had been destroyed and

> "thus commenced another—*a supernatural mode of extinguishing life*—a sudden general destruction of young and old and consequently subsequent to the fulfilment of the physical conditions of many of the beings enveloped".

Since the fossils of the major rock groups were distinctive, Smith concluded that the second creation also was destroyed, being replaced by a third, and that by a fourth,

> "and so on successively by numerous alternations of stratification, numerous repetitions of new creation, physical existences, and destructions by which new species, genera, and families appeared, and others became extinct. Such changes as these which pervade this System must *each* be considered *supernatural*."

Then follows "(?) the cessation of the forming process—*a great supernatural event*" and the "First occurrence of DRY LAND, but in what period of time or in what manner it became dry we know not nor have any data".

Next came "THE CREATION—that of land Animals, the inhabitants of air, and most of those that inhabit the Water, and the great variety of plants that clothe the Earth", followed by "The great *supernatural* event or catastrophe of THE DELUGE known by loose water-worn stones". "The Deluge," he wrote, "which effected (by the agency of water) a most extensive destruction, evinced by bones mixed with debris. By these bones it is ascertained that there were land animals prior to the Deluge, and therefore the land before that catastrophe was dry for their reception and inhabited by them." After the Deluge came a "CHANGE OF CLIMATE—ascertained by bones in the diluvium of cold climates, which belong to animals of a hot climate and by an entire Elephant preserved in the Ice of Siberia—how effected we know not—seemingly a consequence of the Deluge."

Finally we have the "present order of things with a partially colder climate", a period during which animals are "Successively renewed and destroyed in the order of nature".

The table is summarized in two concluding paragraphs. He deduced six distinct "orders of things" with five principal "supernatural events", and numerous "supernatural destructions . . . to all of which the organized fossils are the only clue".

In this scheme,

> "The CREATION is the last, or principal one, of many preceding creations during the Earth's formation under water," and "The Deluge is the last of a long series of supernatural destructions. It is by the help of these, and the peculiar arrangement of the strata, in successively forming parts of the surface, that we are enabled to extend our knowledge deep into the Earth".

Interesting as it is as a record of a great man's thoughts, the broadsheet assumes even greater interest when considered in the light of contemporary geological ideas, and therefore what might have been a mere record of the discovery of the document has been expanded into a short account of an important phase in the history of geology. It may be regarded as a shot in the war between the Uniformitarians and the Catastrophists, but it was a belated shot, for the result of the struggle was already certain some five or six years previously, when Lyell wrote to Gideon Mantell concerning a meeting of the Geological Society in April, 1829 :—

> "The last discharge of Conybeare's artillery . . . drew upon them on Friday a sharp volley of musketry from all sides and such a broadside, at the finale, from Sedgwick as was enough to sink the 'Reliquiae Diluvianae' for ever."

There had been for some time two opposing schools of thought—one, the older, seeing in the hills and valleys and in the variously tilted rocks the work of catastrophes or of outbursts on the part of natural or supernatural forces, and solving, as Bonney remarked, each difficulty with a convulsion; while the other, the younger, held that the rocks were formed and their present situations determined by the long continued operation of just those processes which to-day are slowly but effectually modifying the earth's surface by the formation of valleys and by erosion along the coast.

The discussion was many sided, and, at the time with which we are now concerned, the main point at issue was the part played by the Deluge, a catastrophe, in the formation of rocks and in the modification of the earth's surface features.

The opposing parties were called, by W. D. Conybeare, "Diluvialists" and "Fluvialists" respectively. The former maintained that the Deluge played an important part in developing the present system of hills and valleys and in forming the widespread superficial gravelly deposits, while the latter held that valleys were, for the most part, the work of the streams that flowed in them. This controversy was, in a sense, the final and a minor phase in the greater dispute between the Uniformitarians and the Catastrophists.

The foundation of the Uniformitarian school had been laid by James Hutton towards the end of the eighteenth century. In his *Theory of the Earth* (1785) he argued that rain, wind, and rivers which, as could easily be seen, were slowly wearing rocks away, would, in the course of time, effect profound changes in topography, and moreover, he saw nothing in the rocks to suggest that processes other than those with which we are familiar had been concerned in their formation.

Hutton's views were opposed more or less strenuously in various quarters. Richard Kirwan, the Dublin mineralogist, attacked them with more violence than reason,[1] and John Kidd, the Oxford Professor of Chemistry, concluded that "a very slight review of the changes produced on the surface of the strata by the operation of existing causes will show that these are entirely inadequate to the explanation of the origin of the strata themselves".[2]

They were expounded and illustrated by J. Playfair,[3] and later on were adopted and expanded by Lyell, in whose capable hands the "Uniformitarian" school increased in prestige until one by one the supporters of the Catastrophic theory ceased to take an active part, or went over to the other side.

The discussion was especially acute between 1820 and 1830. W. D. Conybeare, one of the most powerful exponents of Catastrophism, said of Hutton:—

> "He who could perceive in the phenomena of geology nothing but the ordinary operation of actual causes, carried on in the same manner through infinite ages . . . must have surveyed them through the medium of a preconceived hypothesis alone." [4]

He expressed the opinion that the chief defects in the theories of the opposing school were:—

> "First, because, ascribing everything in the formation of valleys to the agency of running waters, they entirely overlook the effect which must

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[1] R. Kirwan, *Geological Essays*, London, 1799.

[2] J. Kidd, *A Geological Essay on the imperfect evidence in support of a theory of the Earth*, Oxford, 1815.

[3] J. Playfair, *Illustrations of the Huttonian Theory of the Earth*, Edinburgh and London, 1802.

[4] W. D. Conybeare and J. Phillips, *Outlines of the Geology of England and Wales*, London, 1822, p. xliv.

> have been produced by the violent convulsions which appear in so many instances to have broken and elevated the strata.
>
> "The second defect . . . is that while they correctly ascribe the excavation of the valleys to the agency of aqueous currents, they look to no other supply of that agency than the streams (often inconsiderable rills) which now flow through them."

Much of the discussion took place at the meetings of the newly-founded Geological Society; on the one side were Conybeare, Buckland, and Greenough, and on the other Sedgwick (although not at first), Murchison, and, most powerful of all, Lyell.

Lyell rejected the hypothesis that forces now unknown were active in earlier epochs and taught that

> "the forces now operating upon and beneath the earth's surface may be the same both in kind and degree with those which at remote epochs have worked out geological revolutions; or in other words, we may dispense with sudden violence and general catastrophes, and regard the ancient and present fluctuations of the organic and inorganic world as belonging to one continuous series governed by uniform laws similar to those now in operation."

This was the thesis of his *Principles of Geology*, from the introduction to which the foregoing words have been quoted.

The ground had already been well prepared for the reception of the "Principles", and its publication may be said to mark the close of the controversy as far as the leaders of geological thought were concerned, although even as late as 1844 a paper was read at the York Meeting of the British Association asserting that a series of rapidly occurring catastrophes had completed the formation of the earth in a few days. This paper will be referred to at a future occasion.

The reasons for the suggestion, previously made (p. 533), that Smith had Lyell's new work in mind when compiling his table of Deductions are as follows :—

He commenced by observing that since some are in doubt "on the PRINCIPLES OF GEOLOGY I shall endeavour to exhibit the principles long familiar to my mind" and, dealing with the periods of stratification, wrote of a "new order of things essentially different from any 'causes now in operation'—distinguished by general destruction".

The quotation marks enclosing "causes now in operation" are in the original, and they are the only words so emphasized in the whole broadsheet. This would suggest that Smith was using what was, at the time, a familiar expression; and those are the very words which Lyell used in the alternative title to the first edition of his Principles—"Principles of Geology; being an Attempt to Explain the Former changes of the Earth's surface by Reference to Causes now in Operation," London, vol. i, 1830. The present title was not adopted until later editions appeared.

It is interesting to note that although in his earlier days Smith had no use for those who invoked "uncommon convulsions" to account for the earth's surface features, in his declining years he wrote of "a series of supernatural destructions mostly effected by the agency of water, which not only gave rise to changes in the earth's

TABLE 1.—Extracts from W. Smith's *Synopsis of Geological Phenomena*, 1832.

SOURCES OF EVIDENCE.	DEDUCTIONS.	RESULTS.
Fishes in abundance	indicate that	Water prevailed.
Petrified shells are so filled . . .	as to evince minute solution . . .	1. Polarity of atoms.
Crystals blunted prior to union in masses .	show aqueous action	2. Crystallization of particles.
Shells in rocks not crushed . . .	therefore rocks hardened quickly . .	3. Aggregation, induration, and cementation of mineralized masses in the *Stratification*.
,, by hardening of matter . . .	were fixed	
,, none in open joints and veins . .	therefore joints and veins opened subsequently to their fixation.	
	* * * * *	
By the remains of land animals mixed up with water-worn stones.	We ascertain that the	Earth was dry and inhabited.
By the boulder-stones everywhere scattered over the earth's surface.	There has been water in action . .	THE DELUGE.
By the fossil shells in those boulders, identified with those in the stratified rocks.	We ascertain the way of action . .	
By the height to which the boulders and sea-shells have been raised.	We get the force of action and height of the water.	

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<table>
<tr><th>I.
CREATIONS OF SOLID INERT MATTER.</th><th>II.
CREATIONS OF ANIMAL AND VEGETABLE LIFE.</th><th>III.
DESTRUCTIONS OF LIFE PHYSICAL AND SUPERNATURAL.</th><th></th></tr>
<tr><td>The primitial interior of the Earth.</td><td>Void of Life.</td><td>None to destroy.</td><td>1st Order of things in which crystalization prevails.</td></tr>
<tr><td colspan="3">(1) This change in the order of things was a general <i>supernatural event.</i></td><td></td></tr>
<tr><td>1st Stratification became the residence of aquatic animals.</td><td>This was <i>the commencement of living beings</i>—a new order of things—physical operations, life, growth, and propagation of species.</td><td><i>Physically</i> subject to the extinction of life, by decay, or by being the prey of other animals.</td><td>2nd Order of created things—distinguished by traces of life.</td></tr>
<tr><td colspan="3">* * * * * *</td><td></td></tr>
<tr><td colspan="3">(3) First occurrence of DRY LAND but in what period of time, or in what manner it became dry we know not, nor have any data.</td><td>4th Order of things inferred from bones in the diluvium.</td></tr>
<tr><td></td><td>THE CREATION—that of land Animals, the inhabitants of air, and most of those that inhabit the Water, and the great variety of plants that clothe the Earth.</td><td><i>Physically</i> renewed and destroyed known by the bones of young animals.</td><td></td></tr>
<tr><td colspan="3">* * * * * *</td><td></td></tr>
<tr><td colspan="3">(4) The great <i>supernatural</i> event or catastrophe of THE DELUGE known by loose water-worn stones.</td><td></td></tr>
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<tr><td colspan="3">(5) CHANGE OF CLIMATE—ascertained by bones in the diluvium of cold climates, which belong to animals of a hot climate and by an entire Elephant preserved in the Ice of Siberia,—how effected we know not—seemingly a consequence of The Deluge.</td><td></td></tr>
</table>

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We have therefore deduced six distinct orders of things, and five principal *supernatural events* (numbered) beside the very numerous consecutive supernatural destructions, resulting from each forming process in the stratification; to all of which the organized fossils are the only clue.

* * * * * *

In the col. II we see that THE CREATION is the last, or principal one, of many preceding creations during the Earth's formation under water; and in col. III that THE DELUGE is the last of a long series of supernatural destructions.

* * * * * *

condition but, annihilating living things, had necessitated successive re-creations.

The explanation lies, no doubt, in the fact that in his retirement he was so intent upon his own self-imposed tasks that he became something of a recluse. In the words of John Phillips, he " mixed too little with younger geologists to make the discovery that on the road which he opened were racers swifter than himself ". He did not realize that his own discovery was to provide the means of solving many of the problems relating to past geographical changes.

In view of the foregoing remarks, it is perhaps not surprising to find that the table of " Deductions " appears to have received little attention at the time of its publication. None of Smith's contemporaries or biographers refer to it, and it must rapidly have passed into oblivion, for the present writer has been unable to learn of any copy other than the one to which this paper relates. That copy owes its preservation to the fact that it had been bound in a copy of Phillips' *Geology of Yorkshire*, purchased some years ago, but it was not noticed until recently. The book belonged at one time to J. E. Lee, author of the *Note Book of an Amateur Geologist*. Lee, born in Hull in 1808, was, in his younger days, a companion of John Phillips, and as such would naturally have been sufficiently interested in the work of William Smith to have preserved a copy of one of his papers, but this makes it all the more surprising that Phillips himself did not appear to be aware of its existence.

On a Black Sand from South-East Iceland.

By Alan Stuart, M.Sc., F.G.S.

So far as the writer is aware, no sodic or " contaminated " rocks have been recorded from Iceland, and it was thought that an examination of some black sand collected by Dr. L. Hawkes, and kindly supplied by him, might reveal the presence of minerals from such rocks.

The wide Hornafjord inlet of South-East Iceland is closed by a sand bar about 15 miles long, and the sample was taken at the easternmost end, where the bar abuts on to the Vestur Horn.

The sand is black, with a small percentage of opaque white grains, has a specific gravity of 2·95, and screening gives a mechanical constitution as follows :—

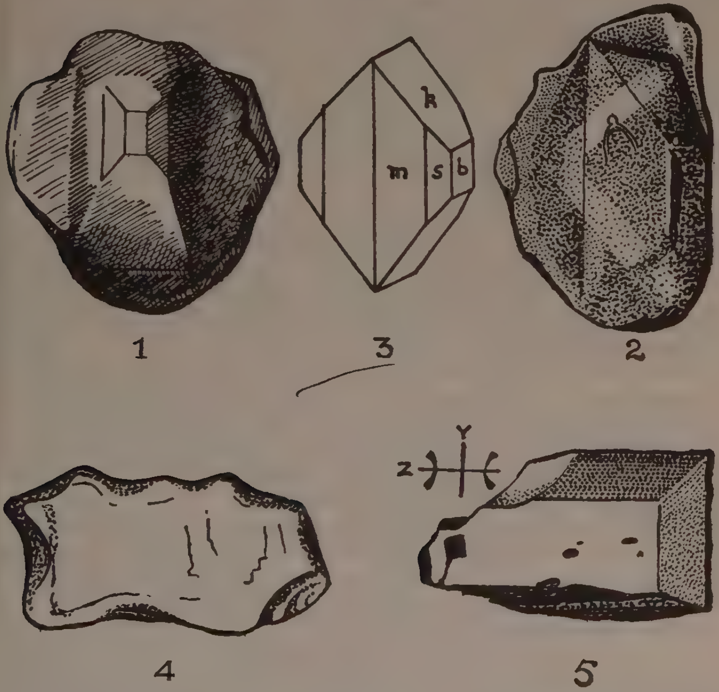
Diameter	> 0·5 mm.	> 0·25 mm.	> 0·10 mm.	< 0·10 mm
Percentage weight	2	20	77·9	0·10

The minerals occurring are : magnetite, ilmenite, quartz, calcite, siderite (?), monoclinic and orthorhombic pyroxenes, olivine, epidote and plagioclase. The bulk of the sand is, however, composed of brown glass. Subordinate amounts of colourless glass, grains which have been interpreted as being quartz-felspar intergrowths, and leucoxene after ilmenite also occur, the last being uncommon.

Description of the Minerals.

The heaviest group (specific gravity $> 3{\cdot}3$) is almost entirely composed of monoclinic and orthorhombic pyroxenes, olivine and black iron ores.

Magnetite and Ilmenite. — Difficulty was experienced in differentiating between these minerals, grains of both being usually irregular and sub-angular, recognisable crystal forms being very rare, only one or two undoubted octahedra being seen. Strong reactions for titanium were given by both the highly and moderately



Olivine Crystals from the Black Sand of the Vestur Horn, S.E. Iceland.

Fig. 1.—Crystal enclosed in brown glass showing *b* (010), *s* (120), *k* (021), and *m* (110), the last not very clearly seen. (× 170.)

Fig. 2.—An enclosed crystal showing *m* (110), *k* (021), *b* (010) being indistinct, *s* (120) not developed—elongation parallel to *c*. (× 180.)

Fig. 3.—Drawing of crystal showing the forms usually occurring in these enclosed crystals.

Fig. 4.—A typical grain showing indications of cleavage and marked conchoidal fracture. (× 150.)

Fig. 5.—A cleavage plate parallel to (010), and perpendicular to the acute bisectrix of negative character—optic axial angle large; (2V near 90°). (× 125.)

magnetic groups on applying the reduction by tin test.[1] It therefore appears that the bulk of the iron ores is magnetic ilmenite, a result to be expected considering the high titanium content of the basalts of the Arctic province.[2]

Olivine has a frequency of 17 per cent in the heaviest crop. In transmitted light it is colourless and water clear; in reflected light some grains are faint yellow or greenish yellow. In shape the grains are sub-angular or rounded, up to ·4 mm. greatest diameter. The highest refractive index measured in ordinary light was 1·70, the maximum double refraction measured being ·035, noticeably higher than that of the augite present. Extinction is straight on unworn crystal edges; the optic axial angle being large (2V near 90°) and negative, indicating an Fe_2SiO_4 content of about 15 per cent.[3] Many cleavage plates normal to a negative bisectrix are presumably parallel to (010). (Fig. 5.)

In the crop with a specific gravity $< 3{\cdot}3 > 2{\cdot}8$ many beautifully preserved olivine crystals are to be seen enclosed in brown glass. (Figs. 1 and 2.) The forms occurring are: m (110), b (010), s (120), and k (021). In one case only, d (101) was doubtfully recognized. The direction of the plane of the optic axes shows that these crystals are elongated parallel to *c*. (Fig. 3.)

Orthorhombic pyroxenes—Hypersthene.—Irregular and more or less prismatic forms occur frequently in the heaviest residues up to ·57 mm. × ·32 mm., showing green (slow) and reddish-brown pleochroism. Light green prisms occur enclosed in colourless glass which has a refractive index lower than canada balsam. These give green (slow) to pale yellow pleochroism.

Monoclinic pyroxenes make up about 70 per cent of the heaviest crop and occur in worn cleavage fragments and prisms, in various shades of brown, purplish brown, and green. Some of the lighter green grains appear to be diopsidic, $Z \wedge c$ clustering round values of 32°, (lime low diopside ?), others show a maximum of $Z \wedge c = 42°$, and positive character of the interference figure. The brown and darker green grains are common augite. Another dark grass-green variety shows a well developed prismatic form, sometimes reaching ·65 mm. long by ·1 mm. broad, very slight pleochroism, maximum refractive index about 1·74 and a double refraction of about ·0267, $Z \wedge c$ being 49°. It is probably an iron-rich diopside.

Epidote occurs sparingly in the heaviest residues in yellowish-green rounded and sub-angular cleavage fragments and grains. In fragments parallel to a perfect cleavage, presumably (001) and showing traces of the (100) cleavage, the pleochroism is very light greenish yellow (fast) to green (slow), straight extinction, and an inclined negative figure is seen in convergent light, the optic axial angle being large.

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[1] G. J. Brush and S. L. Penfield, *Determinative Mineralogy*, 16th ed., 1907, p. 127.

[2] A. Holmes, "The basaltic rocks of the Arctic region": *Min. Mag.*, vol. xviii, p. 180.

[3] S. L. Penfield and E. H. Forbes, "Fayalite from Rockfort, Mass., and on the optical properties of the Chrysolite-Fayalite Group and of Monticellite [Hortonolite]": *Amer. Journ. Sci.*, ser. iv, i, p. 129 (1896).

Plagioclase occurs quite fresh in colourless transparent subangular crystals and cleavage plates usually showing twin striations. The greatest refractive index measured was 1·56, the optic axial angles being near 90° and usually positive. A cleavage plate parallel to (010) gave an extinction angle of $-23°$. The majority of the crystals were labradorite, with a small percentage rather more sodic. Brown glass is a common inclusion, and occasionally swarms of minute black opaque or highly refractive colourless inclusions are present.

Colourless microlites of plagioclase (bytownite) about ·017 mm. average length, having an extinction angle of 49° (α^ length), occur in colourless glass.

Quartz is exceedingly rare (see percentage composition below), and occurs in sub-angular fragments up to ·3 mm. diameter. It is typical of that derived from granite. Some grains with an average refractive index near that of Canada balsam and presenting a mottled appearance between crossed nicols, showing low polarization colours, have been interpreted as being micrographic intergrowths of quartz and felspar. These are scarce.

Glass, mainly brown, but often colourless, forms the bulk of the sand. The differences in refractive index show wide variation in their silica content,[1] the colourless variety of the lightest residue (spec. gravity $< 2·7$), having a value of 1·49 and the dark brown variety, nearly opaque (spec. gravity $< 3·3 > 2·81$), a maximum value of 1·589 + representing a silica percentage of about 72 and 50 per cent respectively.

The darker variety of glass was more vesicular, many fragments showing concave outlines, the lighter and colourless varieties were often crowded with microlites (described above).

Some colourless and light brown grains, sometimes vesicular and exhibiting flow structures, were sometimes almost perfectly spherical, up to ·48 mm. diameter, and between crossed nicols showed a well-marked cross or a pseudo-biaxial figure having a positive character. No radiating fibres could be detected, so tests were made on small glass spheres of similar size[2] to see whether the cross was similar to that due to polarization of light by lenses, but no similar phenomenon could be produced. They recalled the spherulites recorded by Judd[3] from Arran, and called by him opal, and, although these apparently had the same refractive index as the surrounding glass,[1] were soluble in caustic potash solution. The spherulites here described were found to have a refractive index of 1·49, and are insoluble in caustic potash.

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[1] C. E. Tilley, "Density, refractivity, and composition relations of some natural glasses": *Min. Mag.*, vol. xix, pp. 275–94.

[2] Made as described in A. Johannsen, *Manual of Petrographic Methods*, 1918, p. 455, and *Journ. of Geol.*, xxi, 1913, p. 96.

[3] J. W. Judd, "Composite dykes in Arran": *Q.J.G.S.*, vol. xlix, 1893, pp. 549–50.

PERCENTAGE COMPOSITION OF THE SAND.

The percentage weights of the various crops are :—

Specific gravity $< 2{\cdot}8$ . .	29·25
,, ,, $> 2{\cdot}8 < 3{\cdot}3$.	59·25
,, ,, $> 3{\cdot}3$ . .	11·50
	100·00

The percentage frequencies of minerals in each of these crops was found by counting them as they were systematically examined in at least fifty fields of 0·5 mm. diameter for each crop. Knowing the specific gravity of the sand as a whole and the approximate specific gravity of each separation, (taking into account the frequencies of the minerals in each separation and approximating by using the known specific gravities of the minerals), and assuming the sand to be perfectly graded[2] an approximate percentage frequency for the sand as a whole can be calculated. This frequency is expressed below :—

Brown glass	71·14
Monoclinic pyroxene . . .	10·0
Iron ores	5·8
White opaque	5·3
Plagioclase	4·0
Olivine	3·01
Colourless glass . . .	·25
Orthorhombic pyroxene . .	·06
Epidote	·06
Doubtful	·06
Quartz	·02
	99·96

The white opaque minerals are plagioclase, calcite, and micrographic intergrowths. Under "doubtful" above, are included some colourless minerals *either* unstriated plagioclase or quartz which had been permanently mounted before examination, and obscure alteration products.

The examination of this sand has failed to reveal any evidence for a source containing "contaminated" or sodic minerals in this area.

NOTE BY DR. L. HAWKES.

Mr. Stuart's examination of the sand shows that it is an almost pure volcanic ash. The volcanoes which must have provided this basic ash are situated to the west and north-west, probably none of them less than 60 miles distant. With the prevalent westerly winds the ash is distributed widely over Eastern Iceland. Some of it is entangled in vegetation and incorporated in the soil, whilst the remainder was swept along by running water and carried down to the sea, where it bulks largely in shore deposits. On the snowfields of the Vatna Jokull it is buried beneath later falls of snow to appear as dirt bands in the valley glacier outflows from the ice sheet.

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[1] J. W. Judd, op. cit., p. 550, footnote.

[2] The greatest source of error. But the figures given express the composition more truly than is possible with the usual method of denoting frequencies by numbers from 1 to 10.

The rocks of the district are Tertiary plateau-basalts, gabbro and granophyre—which are undergoing rapid disintegration from subaerial agencies as well as from glacial erosion, and it is remarkable that these rocks should contribute so little to the sand.

Ontogenetic and other Variations in *Volutospina spinosa*.

By Alan Stuart, M.Sc., F.G.S., University College, Swansea.

IT has been suggested recently that the concept of a species has only a restricted field of usefulness, its value being most obvious in neontology, and in palaeontology when only one plane in time is considered (12).[1]

When a continuous series of fossil forms from different horizons is considered, it is found that the specimens cannot always be grouped into more or less homogeneous groups or species, because at any one horizon forms occur which show wide variation produced by greater or less acceleration in progressive characters. These forms, which were presumably able to interbreed, produced offspring with variations of the same order, while the group as a whole was advancing, until ultimately forms were produced which by all criteria would be regarded as a new species. The interbreeding of the variants at one horizon in this way produced groups of "individuals with interwoven pedigrees" and "such an evolving stock must be regarded as a 'plexus' or a bundle of anastomosing lineages" (13). The use of forms belonging to such evolving groups in the correlation of sediments has been dealt with elsewhere (6, 14).

It follows that any two individuals from one "plexus" taken at random from one horizon can be supposed to have had a more or less different family history, the amount of difference being limited by the amount of variation displayed by the group at earlier horizons. One would therefore expect because of these differences in ancestral history that the ontogeny of individuals might vary. That this is so can be verified by observation, and has been witnessed to in papers referred to below.

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[1] Numbers in parentheses refer to works quoted at the end of this paper.

While studies have been carried out by several workers in this country on the variation of fossil forms, these studies have been based mainly on shape and the adult characters of the organism (1, 3, 6, 9). Alkins, with certain brachiopods, and Hickling in the case of *Planorbis multiformis,* dealt with the ontogeny of form during growth, the latter noting interesting variations in the development of carination in the above fossil. Very little exact information, however, about variation in fossil forms other than that mentioned is available, and in particular there is little information about variation in ontogeny.

The importance of the study of the ontogeny of the individual in elucidating its family relationships has been emphasized by numerous palaeontologists, notably Mr. S. S. Buckman, in this country. In the study of fossil gastropods, great stress has been laid on the ontogeny of the individual by Grabau, who, writing of the characterization of the genus *Fusus*, says that, in the past, *form* has played the most important rôle, and goes on to say: " The only true guide to relationship in this, as in all cases, must be found in the development of the individual, i.e. its ontogeny, and its relation to that of its group, i.e. its phyletic relation. For this purpose the earliest whorls and particularly the protoconch are of the greatest import " (8, p. 8). He also says that " Two species of gastropods in which the adult characters are similar, but the earlier characters dissimilar, are undoubtedly less closely related than species in which the early stages are similar or identical, and the later stages diverse " (8, p. 2). Again, Professor J. McLean Thompson hopes that by ontogenetic studies new light will be thrown on specific characters and a " revaluation of specific characters obtained " (11). With this trend of thought Dr. L. F. Spath appears to be not wholly in agreement, partly on account of the wide variation in the young of certain species. For instance, he has noted remarkable variation in the young of *Gagaticeras*, the adult whorls of which are indistinguishable, and warns the " compass and graph enthusiast " that the results of a detailed study of these variations are " as futile as those obtained by measuring parts of a suture line " (10). In view of the great variations which appear to exist in certain young forms, a true appreciation of the value to be placed upon the ontogeny of an individual and how it is to be interpreted can only be obtained by detailed investigation by exact methods, and the confident hopes of the former school, or the dark unbelief of Dr. Spath, can only be justified by the results of such studies, which, apart from all other considerations, have undoubtedly a great philosophical interest. The conclusions based upon the new data thus provided will probably be useful in unravelling the antecedents of heterogenetic homœomorphs similar to those described by Mr. S. S. Buckman (2).

The great difficulty in variation studies is the collection of sufficient good material from one horizon, and the author has been exceedingly fortunate in being able to work upon Eocene shells from the excellent collection which the relatives of the late Mr. T. W. Reader presented to the geological department of this college. One hundred and thirty-two shells of *Athleta* (*Volutospina*) *spinosa* (L.), from the Calcaire Grossier of Grignon, France, have been measured, and a few from Damery (not so well preserved) have been compared with these.

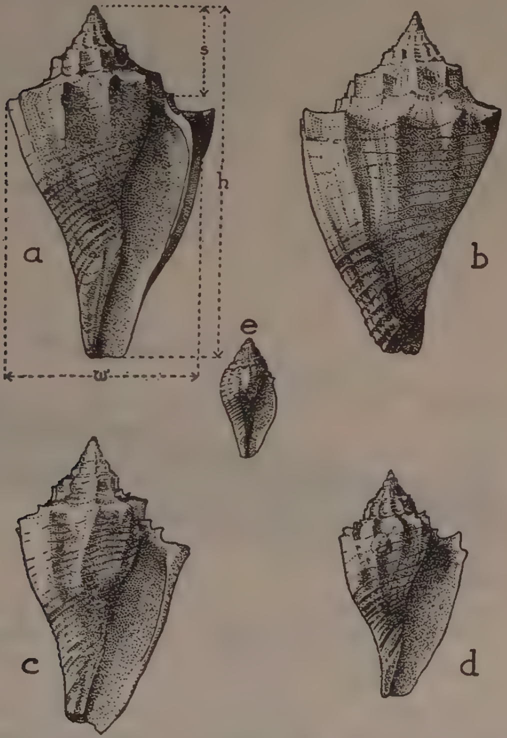

Fig. 1.—Showing specimens of *Volutospina spinosa*. *a* Shows measurements of height (h), breadth (w), and spire height (s); *a* and *b* being the common form. *c* = No. 20, *Volutospina* cf. *trisulcata* (Desh.); *d* = shell No. 50 (see text). *e* = young form of *Volutospina spinosa*. (Natural size.)

The specimens are excellently well preserved, the majority of them retaining the protoconch, all retaining the orange-coloured spiral lines of ornamentation which are so characteristic of the species from this neighbourhood (7). For a general description of the shell the reader is referred to the monograph by Edwards just quoted, or to the publication of the late Dr. A. E. M. Cossman (4). Typical forms are shown in Fig. 1, *a* and *b*.

The measurements of height, breadth, and height of spire were obtained to the nearest 0·01 mm. with a two-way travelling microscope. This accuracy was essential because owing to some shells being much less than 1 cm. in height a value to the nearest 0·5 mm. for the spire height and breadth would have meant a large error. The ontogenetic variations in ornamentation were measured upon an instrument devised for the purpose and shown in Fig. 2. It consists essentially of a bobbin (A), the revolutions of which were measured upon a graduated disc (C) geared to it. The bobbin is a cotton reel adapted by mounting it so as to revolve upon a vertical brass spindle and turning a channel upon it for the belt, which is a violin D string. The disc (C) is graduated in divisions representing whole and one-tenth revolutions of (A), the amount of turning being read off by the pointer (B). The parts are mounted on a sloping base-board so that the shell when mounted with plasticine on (A) will be at right angles to the axis of a binocular telescope through which it is viewed in a strong horizontal beam of light. The gear ratio of bobbin to pulley depends on the size of disc used and the number of whorls to be examined—in this case, a ratio of 12 to 1 was found to be ample, the disc being 8½ inches in diameter.

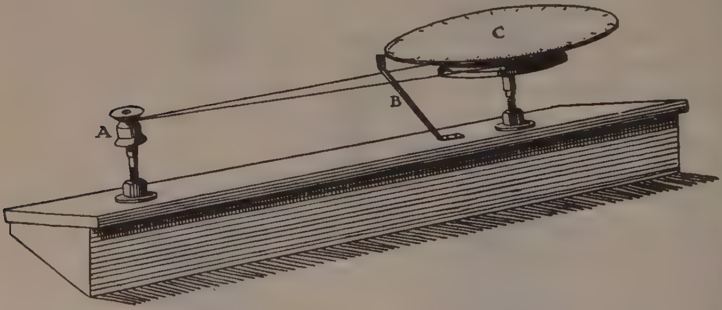

Fig. 2.—Instrument for the measurement of variations in ornamentation of Gastropods.

Variation of Height and Breadth.

The measurements of height and breadth were taken according to Fig. 1*a*. It will be noticed that the greatest breadth in adult shells is at the level of the spines arising from the angle of the body whorl, whereas in young and more fusiform shells it lies somewhat below this line (Fig. 1*e*). In Fig. 3 is shown the graph which results when the height (abscissa) is plotted against the breadth (ordinate). The points cluster fairly closely round a curve (which may not be so regular as shown at the point $h = 30$ mm.), the algebraic formula of which is:—

$$B = 0{\cdot}4444h + 0{\cdot}00256h^2 + 0{\cdot}000027h^3$$

where B is the breadth and h the length of the shell, in millimetres. From this it is evident that the ratio breadth/height increases with age, and that the acceleration of breadth measurements is greater than that of length during the life of the individual. This fact is also shown by Fig. 4, in which three variation curves are plotted showing the value $\frac{\text{breadth}}{\text{height}} \times 100$ for three groups of shells arranged according to size, namely, $<$ 2 cm., $>$ 2 cm. $<$ 3 cm., and $>$ 3 cm. in height. For these three groups this value has a mean of 47·4, 56·3, and 58·1 per cent for the young, medium, and adult shells respectively.

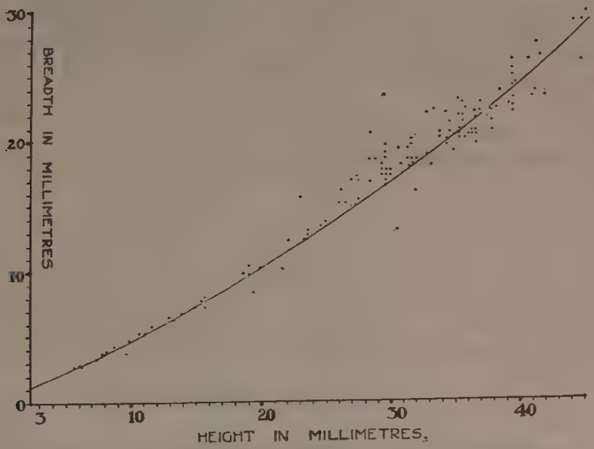

FIG. 3.—Scatter-diagram showing relationship between height and breadth. Algebraic formula of curve: $B = 0{\cdot}4444\,h + 0{\cdot}00256\,h^2 + 0{\cdot}000027\,h^3$.

VARIATION IN THE HEIGHT OF THE SPIRE.

The height of the spire was measured from the tip of the protoconch to the suture (Fig. 1*a*). This is expressed as a percentage of the height of the shell, and these values are plotted in Fig. 5, all shells being included. In Fig. 6 the shells are separated into three groups according to size. The former figure shows that the group is homogeneous with a mean percentage height of 28·3, and the latter that the spire height is greatest in young forms with a mean of 34 per cent, medium shells having 29 per cent and adults 27·6 per cent respectively. As was the case with the ratio $\frac{\text{breadth}}{\text{height}} \times 100$, the greatest change in spire height takes place during youth. Owing to the small number of shells examined in each group the above values can only be regarded as approximate, and for the same reason one is not justified in enlarging upon what appears to be a significant dip in all the graphs in figures 5 and 6 in the region of 33 and 34 per cent. The same observation applies to the double humped curves in Fig. 4.

VARIATIONS IN THE DEVELOPMENT OF ORNAMENTATION.

In order to help the description and discussion of the ontogenetic variations, an ideal development determined from the measurements and the graphs based upon them will be described. This method is adopted in preference to describing one actual development, because it has been found difficult to take a single shell which is typical of the group as a whole and fulfils all the requirements of the facts demonstrated in the graphs.

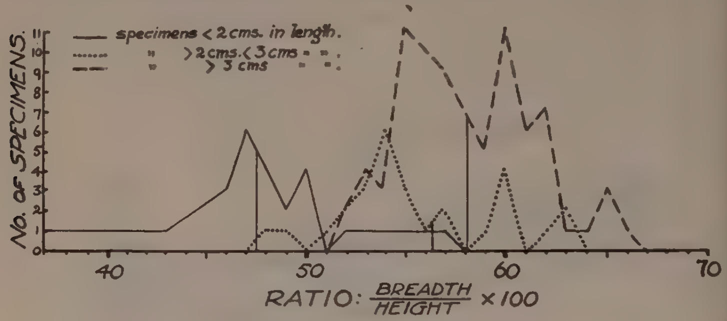

FIG. 4.—Diagram showing relationship between height and breadth for young, medium, and adult shells.

The small homoeostrophic protoconch consists of 2·37 whorls and is unornamented, being perfectly smooth and lustrous. The protoconch is rarely well differentiated from the beginning of the first nepionic whorl, the change to the latter being marked by the appearance of one or two more or less rounded axial ribs. Tubercles now rapidly make their appearance on the following ribs, the first one appearing near the suture at the top of the nepionic whorl, frequently on the second rib, the second tubercle often appearing simultaneously or on the third axial. The third tubercle normally appears on the third rib, the fourth on the fourth or fifth, and the fifth on the eighth rib, the five tubercles having generally appeared within the first third of the nepionic whorl. The five rounded tubercles now remain equally prominent up to the end of the first nepionic whorl, giving the latter a rounded profile, but from this point the first and second tubercles begin to separate, becoming at the same time more prominent, producing a concave surface between them, thus giving to the shell its characteristic angulation at the shoulder of the whorl. Simultaneously with the growth and

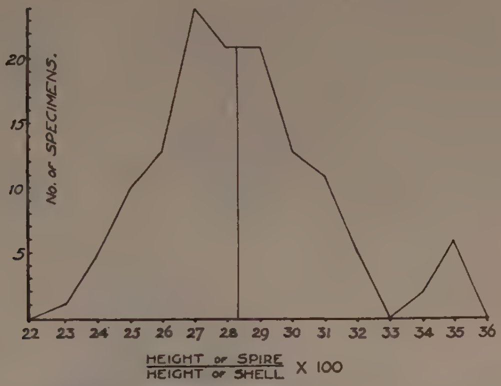

Fig. 5.—Diagram showing variation in the ratio spire height/height of shell for all shells.

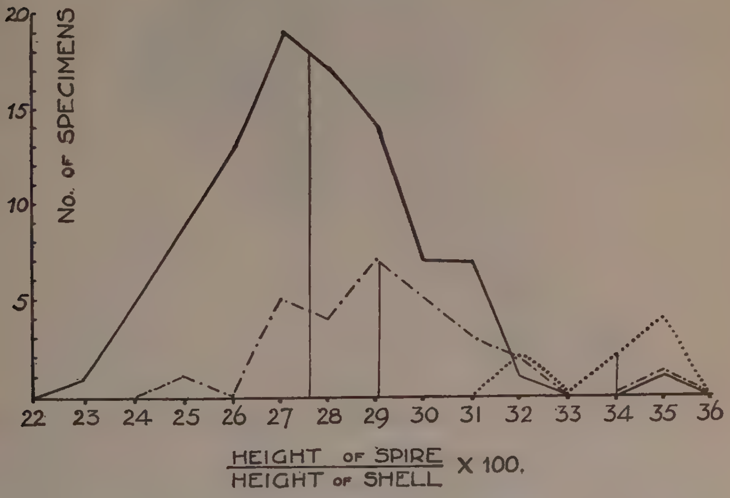

Fig. 6.—Diagram showing the variation in the ratio spire height/height of shell for three groups of shells : ——— shells > 2·5 cms. in height ; —.—. shells < 2·5 cms. > 1 cm. in height ; ..... shells < 1 cm. in height.

eparation of the first and second tubercles, the lower ones disappear n turn, the fifth first, generally at 4·5, the fourth at 5·9, and the hird at 6·8 volutions respectively. This development is shown in Fig. 7. The first and second tubercles increase in size up to about the fifth whorl, becoming gradually spinose, the first tubercle retaining its bulbous character longer, but from this point the first one remains practically stationary in size (or it may be slightly reduced), while the second spine becomes larger still and produces the characteristic sharp angle at the shoulder of the ephebic whorls. In the adult shell the number of whorls is eight and a half. On the body whorls of some adults incipient spines are seen on the concave surface between the first and second spines.

The variations from the ideal ontogeny given above may be studied from the graphs given in figures 8 to 10. In general there

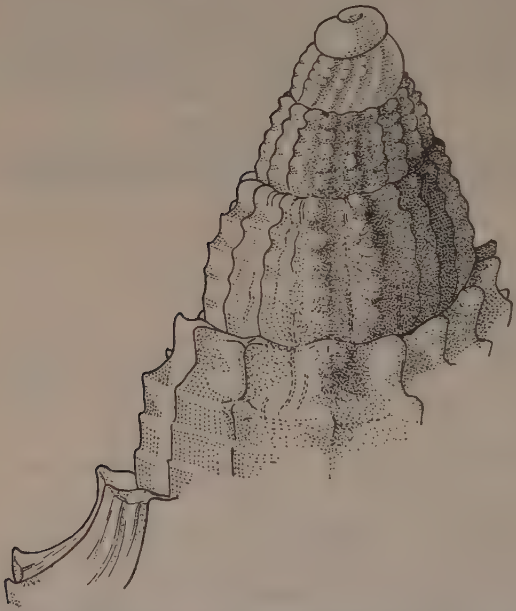

Fig. 7.—Ideal development of ornamentation in *Volutospina spinosa*. (× 20.)

is greater latitude in the appearance of the later tubercles, the fifth showing the greatest variation in this character. Thus in one case all five tubercles appear on the first axial, and in three cases the appearance of the fifth tubercle is delayed until the twentieth axial. Similarly, in its disappearance the fifth tubercle shows greater variation than the fourth and third, the second and first always persisting. The successive narrowing of the graphs in figure 10 demonstrates this.

In order to test the possibility of there being any correlation between the time of appearance of a tubercle and its disappearance, these characters were plotted against one another for the fifth, fourth, and third tubercles. It is found that in each case, when the means are inserted on the graph, that there is a slight preponderance of numbers in the north-west and south-east quadrants.

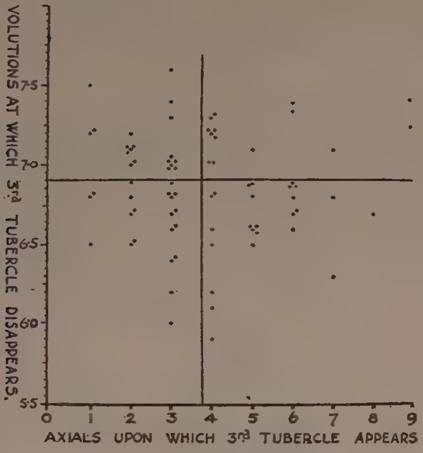

FIG. 8.—Scatter-diagram showing the relation between appearance and disappearance of the third tubercle.

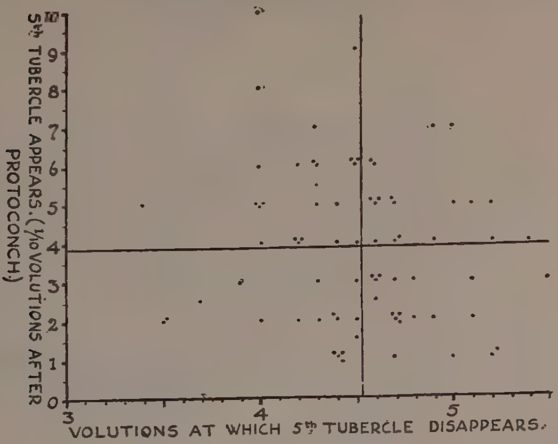

FIG. 9.—Scatter-diagram showing the relation between the appearance and disappearance of the fifth tubercle. Correlation factor = —0·144.

In the first graphs made, the number of the axial upon which a tubercle appeared was plotted against the number of volutions at which it disappeared (Fig. 8), but as it appeared possible that any correlation might be partly obscured in this way, data for the fifth tubercle were collected in which both the appearance and disappearance are expressed in volutions. From the graph so constructed, a greater degree of correlation is in this case definitely shown. The actual value of the correlation factor was worked out in the case of the fifth tubercle from the formula :—

$$r = \frac{\Sigma\, xy}{N\sigma.\sigma_1}, \text{ where}$$

r is the coefficient of correlation.
x is the deviation from the mean of each individual.
y is the deviation from the mean of each individual in the other character.

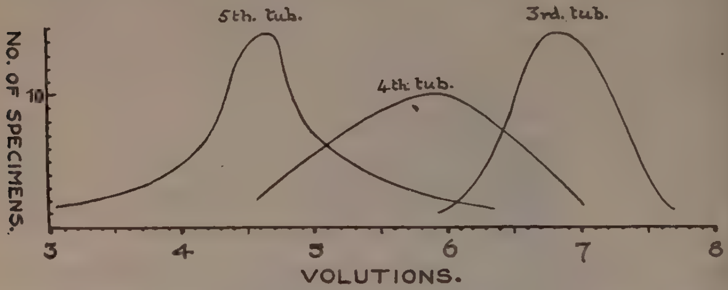

Fig. 10.—Curves showing the variation in the disappearance of the fifth, fourth, and third tubercles.

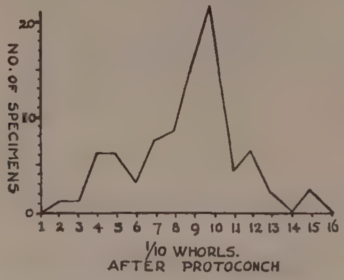

Fig. 11.—Variation diagram to show the point at which separation of the first and second tubercles becomes perceptible.

σ is the standard deviation for x $\left(= \sqrt{\frac{\Sigma\, x^2}{N}}\right)$.
σ_1 is the standard deviation for y.
N is the total number.

This correlation coefficient is $-0{\cdot}144$. In words this may be expressed—that there is a slight tendency for a tubercle to persist during a longer period if it appears relatively early.

VARIATION IN ANGULATION OF THE WHORL.

The progressive separation of the first and second tubercles results in the angulation of the whorls. In Fig. 11 the points at which perceptible separation begins are plotted, and it will be seen that the majority of the shells commence angulation at one volution after the end of the protoconch, only two shells beginning angulation immediately, and in two it is delayed until one and a half volutions after the protoconch.

SPECIAL CASES.

Two shells in the collection (Nos. 20 and 50) are interesting in that they show wider variation in ornament than the others, but they appear to be members of the same community. One of them (No. 20) is in this apparently identical with *Athleta* (*Volutospina*) *trisulcata* (Desh.) (5); the essential difference from the other shells lies in the fact that an extra sulcus is developed between the normal sutural sulcus and the shoulder of the whorl. (See Fig. 1*c*.) This is brought about by the whorl becoming angular at the point of growth of the *third* spine and not the second as is normally the case. The ontogeny is as follows :—The protoconch consists of 2·3 volutions and the nepionic whorl begins with an axial upon which appear two rudimentary oval tubercles. (Fig. 12.) Upon the second, third, fourth, and fifth axials appear three oval tubercles which extend over the whole visible length of the ribs. It appears as if two normal tubercles had become fused, thus producing, instead of six rounded ones, three of oval shape. On the sixth axial the three tubercles bifurcate, producing six normal ones. This occurs at 2·6 volutions. At 3·5 volutions the *third* tubercle begins to separate from the upper two, which latter, while increasing in size, do not begin to separate to produce a sulcus between them until 5·5 volutions, this sulcus being subsidiary to the first formed one. Development is otherwise normal, the sixth tubercle disappearing

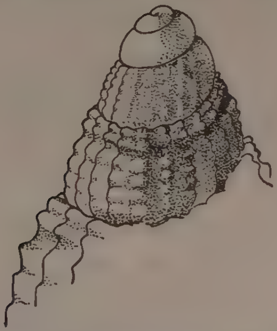

FIG. 12.—The development of ornamentation of shell No. 20. (× 20.)

at 4·4, the fifth at 6·2, and the fourth at 6·7 volutions respectively. In this specimen the first tubercle is dwarfed by the second and third, the shell completing its growth at 8·4 volutions.

In the case of shell No. 50 (Fig. 1*d*), while the second tubercle arises from the angle of the whorl, as is usually the case, the third tubercle, instead of disappearing, persists, forming a short spine on the whorl below the shoulder. The interesting point about the development of the shell is that the rounded profile of the protoconch and nepionic whorl is preserved until 5·5 volutions owing to the equal development of the first three tubercles, after which the first and second separate normally, and the third, instead of disappearing as usual, persists, growing stronger, but remaining subsidiary to the shoulder spine. In No. 50 a tendency towards a trisulcate stage is developed apparently along another path. The ontogeny is summarized below :—

Protoconch, 2·5 volutions.

Two tubercles appear on the first, second, third, and fourth axials.

Three tubercles appear on the fifth axial.

Four tubercles appear on the sixth, seventh, eighth, and ninth axials.

Five tubercles appear on the tenth axial at 2·9 volutions.

The fifth tubercle disappears at 5·2 volutions.

The fourth tubercle disappears at 6·3 volutions.

The third tubercle persists.

Growth is completed at 7·7 volutions.

SUMMARY AND CONCLUSIONS.

One hundred and thirty-two shells of *Athleta* (*Volutospina*) *spinosa* (L.), have been examined, the majority being well enough preserved to permit of detailed measurements being made. The variation in the breadth/height ratio was found to indicate an increase with the age of the individual, approximately according to the equation $B = 0{\cdot}4444h + 0{\cdot}00256h^2 + 0{\cdot}000027h^3$. Spire height expressed as a percentage of the height is greatest in young shells, those less than one centimetre in height having values of thirty-three and thirty-four per cent, whereas fully grown individuals have a mode of twenty-seven per cent.

The variations in ontogeny are not considerable, in only one case have the differences from the normal type been recognized by earlier writers as worthy of specific distinction. It is probable that *Athleta* (*Volutospina*) *trisulcata* (L.) is a variety of *Athleta* (*Volutospina*) *spinosa*.

The correlation between the various ontogenetic factors is small, for example, that for the incidence of the fifth tubercle and its disappearance is only —0·144. On the whole the variations in each of the several characters are independent of the variations in the other characters.

This series of specimens is clearly a group in which the latitude of variation is small, and may be contrasted with such groups as that of *Planorbis multiformis*, in which the variation was described by Professor Hickling (9).

I wish to thank Dr. A. E. Trueman for much helpful criticism and advice during the progress of this work, and Professor E. J. Evans, of the Physics department in this college, for the use of apparatus.

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Chalk Quarry near Black Rabbit Inn, Arundel, Sussex.

By C. T. A. Gaster, F.G.S.

THIS quarry is situated three-quarters of a mile north-east of Arundel Castle on the west bank of the River Arun.

The following paragraph is contained in the Survey Memoirs (1903, p. 30; 1904, p. 53), concerning the Chalk here:—

"A large quarry at the back of the Black Rabbit Inn appears to show the junction of the *M. coranguinum* and *Marsupites* zones. Mr. Hill reports that the lower 60 or 70 feet here exposed consists of firm chalk with many layers of black flints; the upper 50 feet shows soft chalk, with few flints; only a few sparsely scattered nodules or in lines at distant intervals."

Comparison of this paragraph with the results of my investigations on the east side of the river at Burpham and Warning Camp (Pits Nos. 24–8 (1924, pp. 97–8)) gave a discrepancy of some 150 feet in the levels of the Chalk on either side of the river.

I have on two occasions recently visited the Quarry, and as a result have now been able to place the whole of the Chalk in the zone of *Offaster pilula.*

The lower 35–40 feet was accessible, and is in the sub-zone of *Echinocorys scutatus* var. *depressa.* The name fossil was obtained, and a strong marl seam about 35 feet above the base, in the neighbourhood of which at the south end of the quarry I found several specimens of *Echinocorys scutatus* var. *truncatus* and *Offaster pilula*, indicated the junction of the *depressa* sub-zone with the horizon of abundant *O. pilula.*

There is therefore exposed in the upper part of the quarry approximately 80 feet of the sub-zone of *Echinocorys scutatus* var. *cinctus* (1924, p. 94). This yielded *cinctus* and other forms of *E. scutatus* characteristic of the sub-zone.

I have now shown that the whole of the 120 feet Chalk here exposed is in the zone of *Offaster pilula*, and is therefore much higher than recorded in the Survey Memoirs, in fact, it corresponds in position with the Chalk on the east side of the river.

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REVIEWS.

GEOLOGICAL MAPS: THE DETERMINATION OF STRUCTURAL DETAIL. By R. M. CHALMERS, M.C., B.Sc., M.I.M.E. pp. vi + 175, figs. 114. Price 12*s.* 6*d.* Oxford University Press, 1926.

THIS work deals in considerable detail with the problems encountered in obtaining information from the simpler type of geological map. The author treats the problems in the main as being capable of geometrical solution; he labours the mathematical side at times, but illustrates his points by numerous excellent small block diagrams as well as by maps and sections. The chief danger of this method of teaching seems to be that a student may make serious mistakes by failing to realize that strata, in practice, frequently refuse to respond to exact geometrical treatment, although it must be admitted that any training which enables the student to see structures in three dimensions and to realize the principles by which the details may be worked out is of the greatest use. The plan of the book, on the whole, therefore, is admirable, although the drawings of several maps (e.g. figs. 47, 67, 70) contain glaring inaccuracies. "An interesting case of repetition, which the writer has often seen mis-interpreted by students, is shown in Fig. 64." In this case, however, we prefer to identify ourselves with the interpretation given by the student. If it were not for the remarks in the preface, it would be difficult to see the reasons for selection of the works quoted by the author in the bibliography.

W. B. R. K.

ENGINEERING GEOLOGY. By H. RIES and T. L. WATSON. 3rd Edition. pp. vii + 708, 253 figs., and 88 plates. Price 25*s.* 1925.

THIS enlarged edition of a well-known work follows the previous edition after ten years with an increase of price from 17*s.* A lengthy review of the second edition appeared in this Magazine in 1916 (pp. 278–80). In the new edition we have a reproduction after Meinzer of a map of the United States, showing "groundwater provinces" (plate xlvi). This method of dividing the country into districts in which the water supply conditions are more or less uniform appears to be far the simplest and most useful way of imparting valuable information to engineers and others who may not have an expert geological training. The work is a mine of up-to-date information, and the authority for work and figures taken from other sources is so clearly given that with the bibliography after each chapter further information on a subject can be easily found. A brief summary of American stratigraphy is given at the end of the book, but a protest must be made against the statement (p. 656) that "The name Cambrian . . . was first proposed by Sedgwick in 1835 for a group of fossiliferous rocks in North Wales *since shown to be Silurian and Ordovician*".

W. B. R. K.

INTERPRETATION OF TOPOGRAPHICAL AND GEOLOGIC MAPS. By C. L. DAKE and J. S. BROWN. pp. x + 355, figs. 52. McGraw-Hill Publishing Co., Ltd., 1925.

THE work, of which the first 213 pages are devoted to topography, is essentially an explanatory guide to the study of United States Survey maps, and without these maps will lose the greater part of its value for students in this country.

W. B. R. K.

CORRESPONDENCE.

THE PRINCIPLE OF SATURATION IN ROCK-CLASSIFICATION.

SIR,—Professor Shand writes in his last paper on the principle of saturation in rock-classification in the October number of the GEOLOGICAL MAGAZINE: "F. Loewinson-Lessing claims to have put forward a classification of oversaturated and undersaturated rocks in Russia in 1890." It is the first and only time that Professor Shand has cited my name in this question, and I would like this citation to be more correct and adequate to the facts. I not only "claim" to have done it, but, as a matter of fact, I really applied the principle of saturation to the classification of igneous rocks in 1890, not only in a paper in Russian, but also in a paper in French ("Étude sur la composition chimique des roches éruptives" in the *Bulletin de la Société Belge de Géologie*). And again in a new system of classification I made use of the principle of saturation in a book in Russian in 1898, and a year later in my book in German, *Studien über die Eruptivgesteine*, published in the Compte-Rendu of the Seventh International Geological Congress. Hitherto I have never tried to put forward my priority in this question, although Professor Shand has never cited my name. But, when a citation is made, it should be a full citation of my papers where this question is dealt with, and not merely as *claiming* to have done something.

F. LOEWINSON-LESSING.

INDEX

AFRICA, South, Geology of, A. L. du Toit, 282.
Age of Rocks around the Teifi Estuary, J. Challinor, 322.
— of the Earth, Arthur Holmes, 184.
Alkaline rocks, Armenia, G. T. Prior, 285.
Allan, R. S., *Keilorites*, 240.
Ammonites from E. Greenland, L. F. Spath, 474.
Ammonoidea, New, from the Chalk Rock, S. A. Billinghurst, 511.
Analogies between Modern Pools and Carboniferous, Benjamin M. Griffiths, 127.
Ancestors, Our Early, M. C. Burkitt, 138.
Ancon (Ecuador), Clay Pebble Bed of, George Sheppard, 227.
Aporose Morphology, Notes on, J. A. Ryder, 376.
Aramayoite, a new mineral from Bolivia, L. J. Spencer, 90.
— X-ray examination of, K. Yardley, 90.
Atomic volume relations in certain isomorphic series, A. F. Hallimond, 479.
Australian Graptolites, O. A. Jones, 101.
Avonian Brachiopoda, T. Neville George, 106, 193.
— Rocks of Sodbury, Petrology of, A. W. Coysh, 167.

BADDELEYITE, Structure of, K. Yardley, 90.
Baden-Powell, D., Climatic Equivalence of Raised Beach Mollusca, 433.
Bailey, E. B., James Hutton, Father of Modern Geology, 238.
Balsillie, David, Contemporaneous Volcanic Activity in E. Fife, 481.
Baltic Lower Silurian Gasteropoda, Ernst Kokan, 134.
Bather, F. A., *Keilorites*, 286.
Bauxite, C. S. Fox, 381.
Beadnell, H. J. Llewellyn, Wilderness of Sinai, 184.
Beder, R., Ore-deposits of the Argentine, 334.
Bembridge, Flora, Eleanor M. Reid and Marjorie J. Chandler, 135.
Bernicia praecursor gen. et sp. nov., L. R. Cox, 326.
Berz, K. C., Marine Iron Silicates, 331.
β-quartz twins from Cornwall, F. Drugman, 479.
Beyschlag, F., Geological Map of Europe, 477.
Billinghurst, S. A., New Ammonoidea from the Chalk Rock, 511.
Binks, W., Crystalline structure of Zircon, 90.
Biographical notices of mineralogists recently deceased, L. J. Spencer, 286.
Black Sand from S.E. Iceland, Alan Stuart, 540.
Boswell, P. G. H., Purple Zircon in British sedimentary rocks, 479.
— — Some Rare Detrital Minerals, 140.
Brachiopoda, Avonian, T. Neville George, 106.
Brachythyris sulcata sp. nov., 109.
Bremner, Alex., Glacial Geology of N.E. Scotland, 239.
Brown, J. S., Geological and Topographical Maps, 560.
Burkitt, M. C., Our Early Ancestors, 138.

CAMAROPHORIA, Genus of Avonian Brachiopoda II, T. Neville George, 193.
Carboniferous of N. Flintshire, H. C. Sargent, 252.
— of Somerset, F. Dixey, 125.
— of Westmorland, Faults in, A. A. Miller, 80.
— Zones, Todmorden and Grimsworth Dean, W. Lloyd and J. N. Stephens, 284.
Cardiganshire, Glacial Drifts, Kenneth E. Williams, 205.
Carlisle Basin, E. E. L. Dixon and F. M. Trotter, 201.
— — J. W. Gregory, 384.
Cauldrons of Subsidence, E. H. L. Schwarz, 449.
Chalk at Guildford, F. H. Edmunds, 95.
Chalk Quarry, Arundel, Sussex, C. T. A. Gaster, 557.

Chalky Boulder-clay in N.W. Districts of London, H. G. Mantle, 501.

Challinor, J., Age of Rocks around the Teifi Estuary, 322.

Chalmers, R. M., Geological Maps, 559.

Charlesworth, J. Kaye, Drumlins, 157.

Chhibber, H. L., Rhythmic Banding in Rhyolite, 7.

Chubb, L. J., Mangaia and Rurutu, 518.

Classification of Ore-deposits, P. Niggli, 88.

Clay Pebble Bed of Ancon, George Sheppard, 227.

Climatic Equivalence of Raised Beach Mollusca, D. Baden-Powell, 433.

Cockburn, A. M., Geological Notes on the Volcanoes of Hawaii, 187.

Cognate Xenolith, Roxburghshire, W. Manson and R. J. A. Eckford, 239.

Conglomerate near Cairo, J. Cuvillier, 522.

Contemporaneous Volcanic Activity in E. Fife, David Balsillie, 481.

Corals, Lower Cretaceous from E. Venezuela, J. W. Gregory, 440.

Corundum twins, Transvaal, L. J. Spencer, 480.

Cox, L. R., New Lower Carboniferous Gastropod, 326.

Coysh, A. W., Petrology of Avonian Rocks, Gloucestershire, 167.

Cretaceous Crab from Jamaica, T. H. Withers, 176.

— Corals from E. Venezuela, J. W. Gregory, 440.

— Shales of Jamaica, H. L. Hawkins, 142.

— — — C. T. Trechmann, 27, 49.

Cumming, George A., Lower Limestone Rocks, Fifeshire Coast, 188.

Currie, Leslie D., New Synxiphosuran from the Silurian, 153.

— — Obituary Notice of, 190.

Cyamocephalus gen. nov., 153.

Cyamocephalus loganensis, gen. et sp. nov., 154.

DAKE, C. L., Geological and Topographical Maps, 560.

Daly, R. A., Geology of Saint Helena Island, 331.

Davies, A. Morley, Observations on the Geology of Viti Levu, 65.

Davison, Charles, Hereford Earthquake of 1926, 162.

Day, T. Cuthbert, Metasomatism in Basalt, N. Berwick, 188.

— — Old Honestone Quarry near Ratho, 188.

Deductions from Established Facts in Geology, F. J. North, 532.

Deglaciation in Tibet, F. Kingdon Ward, 278.

Deposition of Later Silurian Rocks, English Lake District, J. E. Marr, 494.

Detrital Minerals, Rare, P. G. H. Boswell, 140.

Devon, S.E., Surface Deposits of, W. G. Shannon, 145.

Dibley, G. E., A Rescued Collection, 383.

Dines, H. G., Geology of the Country around Romford, 89.

Dixey, F., Carboniferous of Somerset, 125.

Dixon, E. E. L., Carlisle Basin, 201.

Drugman, J., β-quartz twins from Cornwall, 480.

Drumlins, J. Kaye Charlesworth, 157.

Dry Valley, Onich, Inverness-shire, Frederick Walker, 142.

du Toit, A. L., Geology of S. Africa, 282.

EARLE, K. W., Geology of the West Indies, 191.

Earth Movements and Extinction, H. H. Swinnerton, 529.

Earth's Thermal History, Harold Jeffreys, 444.

Earthquake, Hereford, 1926, Charles Davison, 162.

East Lothian, Notes on the Geology of, John B. Simpson, 46.

Eastern England, Underground Structure of, R. H. Rastall, 10.

Echinoid Illustrations of some Problems in Evolution, H. L. Hawkins, 333.

Eckford, R. J. A., Cognate Xenolith, Roxburghshire, 239.

Edinburgh Geological Society, 45, 141, 187, 238.

Edmunds, F. H., Chalk at Guildford, 95.

— — Geology of the Country around Romford, 89.

— — Pliocene Deposits, South Downs, 287.

Engineering Geology, H. Ries and T. L. Watson, 559.

Eotriassic Ammonites from E. Greenland, F. L. Spath, 474.

Eruptive Rocks, Genesis, Composition, etc., S. J. Shand, 329, 446.
Established Facts in Geology, Deductions from, F. J. North, 532.
Europe, Geological Map of, F. Beyschlag and W. Schriel, 477.
Extinction and Earth Movements, H. H. Swinnerton, 529.
Extrusive Igneous Rocks, Dundee District, John W. Harris, 46.

FAULTS in Carboniferous of Westmorland, A. A. Miller, 80.
Fayum Desert, Northern, Recent Geology of, Elinor W. Gardner, 386.
Fermor, L. L., Kata-Metamorphism or Hypo-Metamorphism, 334.
Field, R. M., Geology Manual, 139.
Fleet, W. F., Heavy Mineral Frequencies, 287.
— — Sandstone with Breccias, S. Warwickshire, 47.
Formation of Lake Geneva, E. Joukowsky, 97.
Fossil Plants, F. H. Knowlton, 526.
Fox, C. S., Bauxite, 381.

GARDNER, ELINOR W., Recent Geology of the Northern Fayum, 386.
Garnets in Regional Metamorphism, C. E. Tilley, 372.
Gaster, C. T. A., Chalk Quarry, Arundel, Sussex, 557.
Gastropod, new, from the Lower Carboniferous, L. R. Cox, 326.
Geneva, Formation of Lake, E. Joukowsky, 97.
Geological Survey of Great Britain, Summary of Progress for 1925, 43.
Geologists' Association, 46, 333.
Geology Manual, R. M. Field, 139.
George, T. Neville, Avonian Brachiopoda, 106, 193.
Ghosh, P. K., Petrology of Bodmin Moor Granite, 479.
Gisortia, Genus, E. Vredenburg, 237.
Glacial Drifts of Cardiganshire, Kenneth E. Williams, 205.
— Geology of N.E. Scotland, Alex. Bremner, 239.
— Tectonics, as reflected in Disturbed Drift Deposits, Geo. Slater, 47.
Glasgow Geological Society, 140, 185, 285.
Graptolites, Silurian, from Australia, O. A. Jones, 101.
Greenwood, G., Rotating crystal x-ray photographs, 285.
Gregory, J. W., Carlisle Basin, 384.
— — Jurassic Fossils from Kenya Colony, 325.
— — Lochs of the Outer Hebrides, 140.
— — Lower Cretaceous Corals, 440.
Griffiths, Benjamin M., Modern Pools and Carboniferous Analogies, 127.
Groves, A. W., Plutonic Rocks of the Channel Islands, 241, 457.
Gypsum in Tertiary Clays, Ecuador, George Sheppard, 298.

HALLIMOND, A. F., Atomic volume relations in certain isomorphic series, 479.
Harrasowitz, Hermann, Laterite, 476.
Harris, John W., Extrusive Igneous Rocks, Dundee District, 46.
Harwood, H. F., Separation of Manganese in rock analysis, 480.
Hattonia gen. nov., 438.
— *etheridgei* sp. nov., 438.
Hawkins, Herbert L., Cretaceous Shales of Jamaica, 143.
— — Echinoid Illustrations of some Problems in Evolution, 333.
Heavy Mineral Frequencies, W. F. Fleet, 287.
— — — Alan Stuart, 143.
— — Plutonic Rocks of the Channel Islands, A. W. Groves, 241, 457.
Hereford Earthquake of 1926, Charles Davison, 162.
Historical Geology, W. J. Miller, 138.
Holmes, Arthur, Age of the Earth, 184.
— — Problems of Physical Geology, 263.
— — Radioactivity of Potassium, 478.
Holocystis Ed. & Haime, T. A. Ryder, 119.
Holt, E. V., Separation of Manganese in rock analysis, 480.
Holywell Shales, N. Flintshire, H. C. Sargent, 336.
Hone-stone Quarry near Ratho, T. Cuthbert Day and David Tutt, 188.
Hudson, R. G. S., Mid-Avonian Reef in Craven Lowlands, 503.
Hutton, James, Father of Modern Geology, E. B. Bailey, 238.
Hyphantoceras sp. nov., 513.

ICELAND, Black Sand from, Alan Stuart, 540.
Igneous Rocks of Baxter's Bank,
Iron Ores, Reports on Mineral Resources of Great Britain, 478.

JAMAICA, Cretaceous Shales of, C. T. Trechmann, 27, 49.
Jeffreys, Harold, Earth's Thermal History, 444.
Jones, O. A., Australian Graptolites, 101.
— — New Genus of Tabulate Corals, 438.
Joukowsky, E., Formation of Lake Geneva, 97.
Jurassic Cephalopod Fauna of Kachh, L. F. Spath, 282.
— Fossils from Kenya Colony, J. W. Gregory, 325.

KAINOZOIC Dykes of the Clyde Region, G. W. Tyrrell, 185.
Kaiso Bone-beds, E. J. Wayland, A. T. Hopwood, W. E. Swinton, E. I. White, and L. R. Cox, 184.
Kata-Metamorphism or Hypo-Metamorphism, L. L. Fermor, 334.
Keilorites, R. S. Allan, 240.
— F. A. Bather, 286.
Kenya Colony, Jurassic Fossils from, J. W. Gregory, 325.
Kinta Valley, Limestone of, R. H. Rastall, 410.
Knowlton, F. H., Fossil Plants, 526.
Koken, Ernst, Baltic Lower Silurian Gasteropoda, 134.

LAMPLUGH, George William, Obituary notice of, 91.
Later Silurian Rocks, English Lake District, J. E. Marr, 494.
Laterite, Hermann Harrasowitz, 476.
Lewes, Geology of, H. J. Osborne White, 89.
Limestone, Kinta Valley, Malay States, R. H. Rastall, 410.
— and Conglomerate in Craven Lowlands, R. G. S. Hudson, 503.
Lloyd, W., Carboniferous Zones, Todmorden and Grimsworth Dean, 284.
Lochs of the Outer Hebrides, J. W. Gregory, 140.
Loewinson-Lessing, E., Principle of Saturation in Rock-Classification, 560.
Lowe, E. E., Igneous Rocks of Mountsorrel District, 139.
Lower Carboniferous Succession in Westmorland Pennines, J. Selwyn Turner, 333.
— Limestone Rocks, Fifeshire Coast, George A. Cumming, 188.

MACKIE, William, Heavy Minerals in Torridon Sandstones, Scotland, 141.
Mangaia and Rurutu, Comparison between two Pacific Islands, L. J. Chubb, 518.
Manganese, separation in rock analysis, E. V. Holt and F. H. Harwood, 480.
Manson, W., Cognate Xenolith, Roxburghshire, 239.
Mantle, H. G., Chalky Boulder-clay in N.W. London, 501.
— — Quartzite Pebble in Coal, 123.
Maps, Geological, Determination of Structural Details, R. M. Chalmers, 559.
Maps, Geological and Topographical, Interpretation of, C. L. Dake and J. S. Brown, 560.
Marine Iron Silicates, K. C. Berz, 331.
Marr, J. E., Deposition of Later Silurian Rocks, English Lake District, 494.
Martinia multicostata sp. nov. 114.
Matley, C. A., Observations on the Geology of Viti Levu, 65.
Melilite-spurrite-Ca_2SiO_4 assemblage from Antrim, C. E. Tilley, 285.
Metasomatism in Basalt, N. Berwick, T. Cuthbert Day, 188.
Mid-Avonian Reef in Craven Lowlands, R. G. S. Hudson, 503.
Miller, A. A., Faults in Carboniferous of Westmorland, 80.
Miller, W. J., Historical Geology, 138.
Mineralogical Society, 90, 285, 479.
Minerals in Torridon Sandstones, Scotland, William Mackie, 141.
Mining Geology, James Park, 332.
Modern Pools and Carboniferous Analogies, Benjamin M. Griffiths, 127.
Morvern, Physiography and Geology of, J. F. Scott, 186.
Mountsorrel District, Igneous Rocks of, E. E. Lowe, 139.

NEW Ammonoidea from the Chalk Rock, S. A. Billinghurst, 511.
Niggli, P., Classification of Ore-deposits, 88.
Nodularia vitiensis sp. nov., 74.
North, F. J., Deductions from Established Facts in Geology, 532.
Nummulitic Formation near Cairo, Conglomerate in, J. Cuvillier, 522.

Nyasaland Protectorate, Ann. Rep. Geol. Surv. Dept., 1925, 45.

OBITUARY :—
—George William Lamplugh, 91.
—Arthur Walton Rowe, 93.
—Charles Doolittle Walcott, 189.
—Leslie D. Currie, 190.

Oil, Oil-shale and Coal, Geology of, Murray Stuart, 86.
Old Red Sandstone of the Welsh Border, S. W. Wooldridge, 95.
Olivine Group, Unnamed Mineral of the, C. E. Tilley, 143.
Ontogenetic and other Variations in *Volutospina spinosa*, Alan Stuart, 545.
Ore deposits of the Argentine, R. Beder, 332.
Orford Ness, Coastal Physiography, J. A. Steers, 46.
Oxford District, Natural History of, J. J. Walker, 139.
— Country round, Geology of, J. Pringle, 476.

PACIFIC Islands, Mangaia and Rurutu, L. J. Chubb, 518.
Park, James, Mining Geology, 332.
Petroliferous Sandstones in Carboniferous Rocks of Scotland, D. Tait, 45.
Petrology of Avonian Rocks, Gloucestershire, A. W. Coysh, 167.
— of Bodmin Moor granite, P. K. Ghosh, 479.
— Principles of, G. W. Tyrrell, 147.
Phacopidae, Recent Work on the, F. R. Cowper Reed, 308, 337.
Physico-Chemical Geology, R. H. Rastall, 382.
Pia, J., Plants as Rock-builders, 87.
Plants as Rock-builders, J. Pia, 87.
Plant Petrefactions in the Pennant Rock, Clarence A. Seyler and Herbert J. Williams, 96.
Pliocene Deposits, South Downs, F. H. Edmunds, 287.
Plutonic Rocks of the Channel Islands, A. W. Groves, 241, 457.
Post-Glacial Erosion Theory of Drumlins, J. Kaye Charlesworth, 157.
Potassium, Radioactivity of, A. Holmes and R. W. Lawson, 478.
Poulsen, Chr., Trilobites from Greenland, 524.
Pre-Cambrian Shield of Canada, Classification of, M. E. Wilson, 1.
Pringle, J., Geology of Country around Oxford, 476.
Prionocyclus hitchinensis sp. nov., 513.
Prionotropis cristatus sp. nov., 513.
Prior, G. T., Alkaline rocks, Armenia, 285.
Problems of Classification in the Canadian Pre-Cambrian Shield, M. E. Wilson, 1.
— of Physical Geology, Arthur Holmes, 263.
Promicroceras, Observations on the genus, Daisy M. Williams, 76.

QUARTZITE Pebble in Coal, H. G. Mantle, 123.

RADIOACTIVITY of Potassium, A. Holmes and R. W. Lawson, 478.
Radnorshire, Igneous Rocks, R. O. Roberts, 289.
Raised Beaches, Climatic Correlation of, W. B. Wright, 526.
— Beach Mollusca, Climatic Equivalence of, D. Baden-Powell, 433.
Ranina trechmanni sp. nov., Cretaceous Crab from Jamaica, T. H. Withers, 176.
Rastall, R. H., Limestone of the Kinta Valley, 410.
— — Physico-Chemical Geology, 382.
— — Underground Structure of Eastern England, 10.
Recent Geology of Northern Fayum Desert, Elinor W. Gardner, 386.
Reed, F. R. Cowper, Recent Work on the Phacopidae, 308, 337.
Reid, Eleanor M., Bembridge Flora, 135.
Rescued Collection, G. E. Dibley, 383.
Rhythmic Banding in Rhyolite, H. L. Chhibber, 7.
Richardson, L., Sandstone with Breccias, S. Warwickshire, 47.
Ries, H., Engineering Geology, 559.
Roberts, R. O., Igneous Rocks of Baxter's Bank, 289.
Rocks around the Teifi Estuary, Age of, J. Challinor, 322.
Rock-Classification, Principle of Saturation in, F. Loewinson-Lessing, 560.
Romford, Geology of, H. J. Osborne White, 89.
Rotating crystal X-ray photographs, G. Greenwood, 285.

Rowe, Arthur Walton, Obituary notice of, 93.
Ryder, T. A., *Holocystis*, 119.
— — Notes on *Sphenotrochus crispus*, 376.

SAINT Helena Island, Geology of, R. A Daly, 331
Sandstones with Breccias, S. Warwickshire, L. Richardsòn and W. F. Fleet, 47.
Sargent, H. C., Carboniferous of N. Flintshire, 252.
— — Holywell Shales of N. Flintshire, 336.
Schultenite, a new mineral from S.W. Africa, L. J. Spencer, 90.
Schwarz, E. H. L., Cauldrons of Subsidence, 449.
Scotland, N., Geological Notes, A. G. Steavenson, 285.
Scott, J. F., Physiography and Geology of Morvern, 186.
Sedimentation, Treatise on, W. Twenhofel, 180.
Seyler, Clarence A., Plant Petrefactions in the Pennant Rock, 96.
Shand, S. J., Eruptive Rocks, Genesis, Composition, etc., 329.
— — Silica, Alumina, and Bases in Rocks, 446.
Shannon, W. G., Surface Deposits of S.E. Devon, 145.
Sheppard, George, Clay Pebble Bed of Ancon, 227.
— — Gypsum in Tertiary Clays, Ecuador, 298.
Silica, Alumina and Bases in Rocks, S. J. Shand, 446.
Silicified Rhyolite Tuffs showing Rhythmic Bandings, H. L. Chhibber, 7.
Simpson, John B., Notes on the Geology of East Lothian, 46.
Sinai, Wilderness of, H. J. L. Beadnell, 184.
Slater, George, Glacial Tectonics, 47.
Spath, L. F., Eotriassic Ammonites from E. Greenland, 474.
— — Jurassic Fauna of Kachh, 282.
Spencer, L. J., Biographical notices of mineralogists recently deceased, 286.
— — Corundum twins, Transvaal, 480.
— — Schultenite, a new mineral from S.W. Africa, 90.
Sphenotrochus crispus, structure of, T. A. Ryder, 376.
Stamp, L. Dudley, Varved Tertiary Sediments of Burma, 48.
Steavenson, A. G., Geological Notes, 285.
Steers, J. A., Orford Ness, Coastal Physiography, 46.
Stephens, J. N., Carboniferous Zones, Todmorden and Grimsworth Dean, 284.
Stratigraphical Horizon of Holywell Shales, N. Flintshire, H. C. Sargent, 252.
Structure of Baddeleyite, 90.
— and Development of *Holocystis* Ed. and Haime, T. A. Ryder, 119.
Stuart, Alan, Heavy Mineral Frequencies, 143.
— — Black Sand from Iceland, 540.
— — Variations in *Volutospina spinosa*, 545.
— Murray, Geology of Oil, Oil Shale, and Coal, 86.
Subsidence, Cauldrons of, E. H. L. Schwarz, 449.
Surface Deposits of S.E. Devon, W. G. Shannon, 145.
Sussex Chalk Quarry, C. T. A. Gaster, 557.
Swinnerton, H. H., Earth Movements and Extinction, 529.
Synxiphosuran, New, from Silurian, Lanarkshire, L. D. Cutrie, 153.

TABULATE Corals, New South Wales, New Genus, O. A. Jones, 438.
Tait, D., Petroliferous Sandstones in Carboniferous Rocks of Scotland, 45.
Tertiary Clays, Ecuador, Gypsum in, George Sheppard, 298.
Thermal History of the Earth, Arthur Holmes, 263.
— — — Harold Jeffreys, 444.
Tibet, Deglaciation in, F. Kingdon Ward, 278.
Tilley, C. E., Garnets in Regional Metamorphism, 372.
— — Melilite - spurrite - Ca_2SiO_4 assemblage from Larne, 285.
— — Unnamed Mineral of the Olivine Group, 143.
Trechmann, C. T., Cretaceous Shales of Jamaica, 27, 49.
Trilobites from Greenland, Chr. Poulsen, 524.
Trotter, F. M., Carlisle Basin, 201.
Twenhofel, W., Treatise on Sedimentation, 180.

Tyrrell, G. W., Kainozoic Dykes of the Clyde Region, 185.
— — Principles of Petrology, 137.

UGANDA Protectorate, Ann. Rep. Geol. Surv. Dept., 1925, 54.
Ulocrinus and *Hydreionocrinus*, Variations in, James Wright, 353.
Underground Structure of Eastern England, R. H. Rastall, 10.

VARVED Tertiary Sediments of Burma, L. Dudley Stamp, 48.
Vesuvianite and Grossular Products of Regional Metamorphism, C. E. Tilley, 372.
Viti Levu, Observations on the Geology of, C. A. Matley and A. Morley Davies, 65.
Volcanic Activity in E. Fife, David Balsillie, 481.
Volcanoes of Hawaii, Geological Notes on, A. M. Cockburn, 187.
Volutospina spinosa, Variations in, Alan Stuart, 545.
Vredenburg, E., Genus *Gisortia*, 237.

WALCOTT, Charles Doolittle, Obituary notice of, 189.
Walker, Frederick, Dry Valley, Onich, Inverness-shire, 142.
Walker, J. J., Natural History of Oxford District, 139.
Ward, F. Kingdon, Deglaciation in Tibet, 278.
Watson, T. L., Engineering Geology, 559.
Wayland, E. J., Kaiso Bone-beds, 184.
West Indies, Geology of, K. W. Earle, 191.
White, H. J. Osborne, Geology of the Country near Lewes, 89.
Whitby Museum, 385.
Williams, Daisy M., Observations on the genus *Promicroceras*, 76.
— Herbert J., Plant Petrefactions in the Pennant Rock, 96.
— Kenneth, E., Glacial Drifts of Cardiganshire, 205.
Wilson, M. E., Problems of Classification in the Canadian Pre-Cambrian Shield, 1.
Withers, Thomas H., Cretaceous Crab from Jamaica, 176.
Wooldridge, S. W., Old Red Sandstone of the Welsh Border, 95.
Wright, James, Variations in *Ulocrinus* and *Hydreionocrinus*, 353.
— W. B., Climatic Correlation of Raised Beaches, 526.

YARDLEY, K., X-ray Examination of Aramayoite, 90.
Yorkshire Geological Society, 284.

ZIRCON, Crystalline Structure of, W. Binks, 90.
— Purple in British sedimentary rocks, P. G. H. Boswell, 479.

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